# PALAEOGEOGRAPHICAL IMPLICATIONS OF TWO SILURIAN SHELLY FAUNAS FROM THE ARRA MOUNTAINS AND CRATLOE HILLS, IRELAND

*by* J. A. WEIR

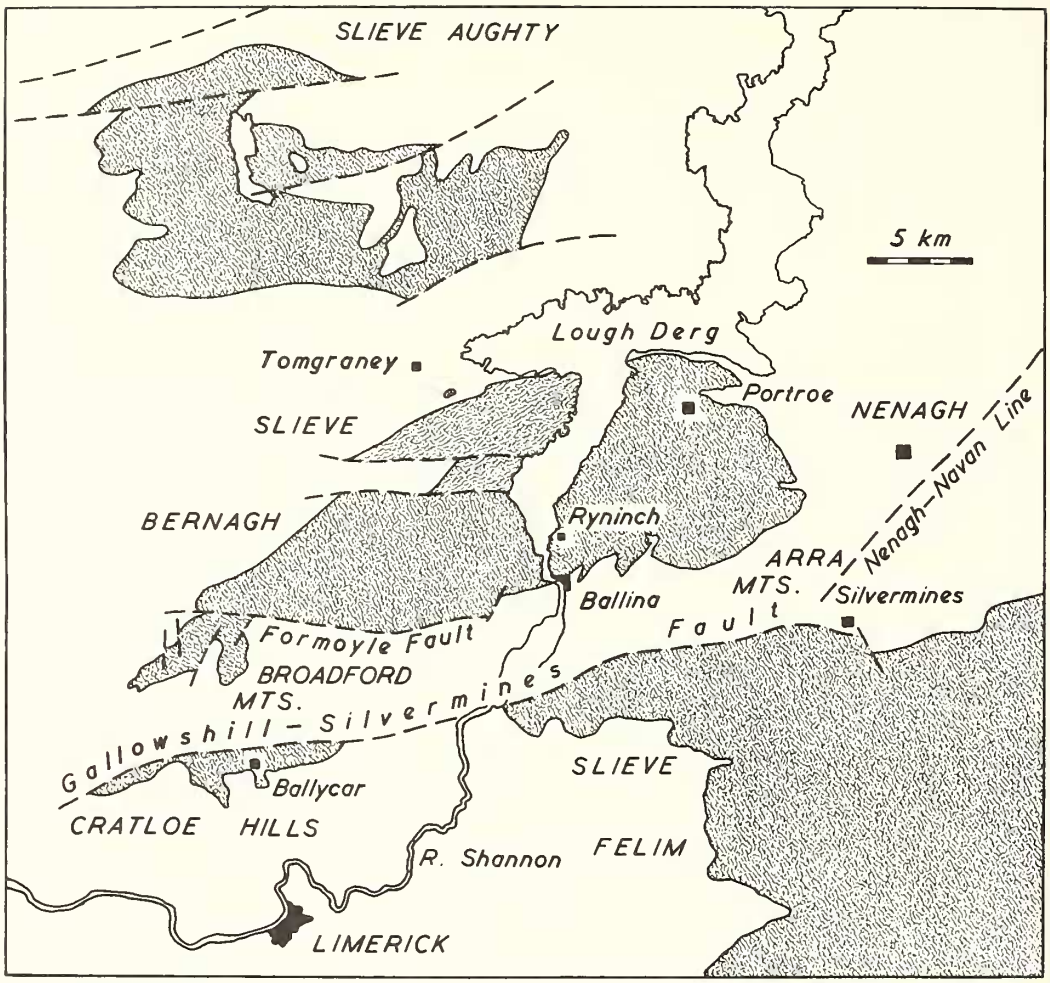
ABSTRACT. A shelly fauna occurring in the Arra Mountains near Ballina, Co. Tipperary, is correlated with a fauna from Ballycar in the Cratloe Hills inlier, South Clare, and assigned to the upper Wenlock. The faunas are considered to have been derived from a shelf area situated to the south-east, and to have been transported north-westwards towards a basin limited south-eastwards and southwards by the Nenagh–Navan Line and by the Gallowshill–Silvermines Fault.

Two shelly faunas, occurring in the vicinity of Limerick, reinforce Harper and Brenchley's diagnosis (1972) of an area of shelf deposition incorporating certain Lower Palaeozoic inliers of the Central Plain of Ireland. Harper and Brenchley consider that the shelf, which may conveniently be designated the Limerick–Tipperary shelf, is bounded to the north-west by a line, referred to herein as the Nenagh–Navan Line, related to a probable pre-Carboniferous fault with a north-westerly downthrow. This approaches, and may join, the Gallowshill–Silvermines Fault, which throws down to the north and forms the northward limit of the Cratloe Hills and Silvermines inliers, which are situated on the shelf (Harper and Brenchley 1972).

Mixed shelly and graptolitic faunas dominate the Limerick–Tipperary shelf. Orthocone nautiloids intimately associated with thin-shelled brachiopods (*Glassia*) occur, along with thin-shelled bivalves and phyllocarids (Cope 1954, 1959; Weir 1962, p. 251). They indicate tranquil conditions and considerable depths of deposition, and are considered to be autochthonous. The sediments are chiefly siltstone-banded argillites with a small proportion of arenaceous and conglomeratic horizons, some of which are probably fluxoturbidites. The succession in the Cratloe Hills inlier is incomplete due to strike faulting, and no meaningful estimate of thickness can be given.

One such sandstone bed, cropping out in Ballycar South townland in the Cratloe Hills inlier (Baily *in* Foot and Kinahan 1862; Weir 1962, p. 249) yields a shelly fauna. Five metres of sandstone are exposed in a prominent scrub-covered knoll at the edge of a field 100 m west of the Oatfield–Limerick road, and 400 m south of the summit of the road (Irish Grid reference R 565636). The rock is strongly calcified and contains sporadic fossils, mostly brachiopods, and occasional rounded quartz pebbles up to 1 cm long. Though most of the brachiopod valves are preserved unbroken they are always disarticulated, indicating that (unlike those of the associated banded argillites, etc.) the fauna is allochthonous. The fauna cannot, however, have been far transported, as there is little evidence of preferential concentration of flat or convex valves

[Palaeontology, Vol. 18, Part 2, 1975, pp. 343–350.]




TEXT-FIG. 1. Locality map of the Limerick area. Lower Palaeozoic inliers shaded. Broken lines, faults; complete lines, stratigraphical contacts. Fossil localities of Ballycar (Cratloe Hills) and Ryninch (Arra Mountains) indicated.

(cf. Boucot, Brace and deMar 1958; Martin-Kaye 1951). The locality lies about 1 km south of the Gallowshill Fault.

The basin facies, occurring in the Slieve Bernagh–Arra Mountains and Slieve Aughty inliers, has virtually no autochthonous fauna. In Slieve Bernagh the sediments (Weir 1962) constitute a major 'fining-upwards' cycle, with a basal development of arenite-bearing argillites more sparsely banded but containing occasional thick and coarse conglomerate horizons again probably to be interpreted as fluxoturbidites. Two shelly faunas have been located within the basin; corals have been recorded from one locality in the north-east of the Slieve Bernagh inlier (Baily *in* Foot and Kinahan 1862, p. 17), and a shelly conglomerate (discussed herein) occurs in Ryninch Upper townland in the Arra Mountains. The bed is less than 1 m thick, and is exposed in a small quarry (R 706747) in a field 2 km due north of Killaloe

Bridge, Ballina, and 200 m west of the Ballina–Portroe road. The locality is not reported specifically in the sheet memoir (Foot 1861). The conglomerate (or pebbly sandstone) resembles that at Ballycar, though it is more feldspathic. The fossils occur mostly in thin lenses of rottenstone distributed irregularly through the bed, though occasional isolated shells occur. The rottenstone consists essentially of weathered and comminuted shell debris and crinoid ossicles, together with less fragmentary shells, mostly brachiopods. In general, only the umbonal ends are preserved. There is a very strong selective concentration in favour of convex valves, resulting in a bias towards preservation of dalmanellid pedicle valves. This selective concentration and the fragmentary state of the material again point to allochthonous origin, but contrast with the Cratloe locality, denoting a considerably greater distance of transport.

The following faunas have been collected from the two localities (Ballycar, Geological Survey of Ireland collection and author's collection; Ryninch Upper, author's collection):

TABLE 1

| | Ballycar | | Ryninch Upper | |
|---|---|---|---|---|
| | 1 | 2 | 1 | 2 |
| (1 = number of specimens; 2 = percentage of total collection) | | | | |
| rugose corals | 33 | 14·7 | — | — |
| favositids | 5 | 2·2 | — | — |
| heliolitids | 2 | 0·9 | — | — |
| *Halysites* | 10 | 4·5 | — | — |
| *Aulopora* | 1 | 0·4 | — | — |
| ?*Aulopora* | 1 | 0·4 | — | — |
| tabulate corals indet. | 3 | 1·3 | — | — |
| bryozoa | 8 | 3·6 | 1 | 0·9 |
| *Craniops* | 4 | 1·8 | 1 | 0·9 |
| orthids indet. | 2 | 0·9 | 2 | 1·7 |
| ?orthids | — | — | 1 | 0·9 |
| ?*Dolerorthis* | 5 | 2·2 | 3 | 2·6 |
| *Salopina* | 4 | 1·8 | 3 | 2·6 |
| ?*Isorthis* | 1 | 0·4 | 11 | 9·6 |
| *Resserella* | 14 | 6·3 | 21 | 18·3 |
| ?*Resserella* | 1 | 0·4 | 4 | 3·5 |
| *Dicoelosia biloba* (Linnaeus) | 4 | 1·8 | — | — |
| enteletaceids indet. | 5 | 2·2 | 1 | 0·9 |
| *Leptostrophia* | — | — | 1 | 0·9 |
| ?*Leptostrophia* | 1 | 0·4 | — | — |
| *Leangella segmentum* (Angelin) | 16 | 7·1 | — | — |
| *Eoplectodonta duvalii* (Davidson) | 2 | 0·9 | 3 | 2·6 |
| ?*Eoplectodonta* | 1 | 0·4 | — | — |
| *Pentlandina* | 2 | 0·9 | — | — |
| ?*Pentlandina* | 1 | 0·4 | — | — |
| *Leptaena* | 5 | 2·2 | — | — |
| *Strophonella* | 5 | 2·2 | 4 | 3·5 |
| stropheodontids indet. | 3 | 1·3 | — | — |
| strophomenaceids indet. | 4 | 1·8 | — | — |
| *Coolinia* | 3 | 1·3 | — | — |
| orthotetids indet. | 1 | 0·4 | — | — |
| ?orthotetids | — | — | 2 | 1·7 |
| *Anastrophia* | 2 | 0·9 | — | — |

TABLE 1 (*cont.*)

| | Ballycar | | Ryninch Upper | |
|---|---|---|---|---|
| | 1 | 2 | 1 | 2 |
| (1 = number of specimens; 2 = percentage of total collection) | | | | |
| *Clorinda* | 8 | 3·6 | — | — |
| pentamerids indet. | 3 | 1·3 | — | — |
| *Sphaerirhynchia* | 1 | 0·4 | — | — |
| rhynchonellids indet. | 8 | 3·6 | 11 | 9·6 |
| *Atrypa reticularis* (Linnaeus) | 5 | 2·2 | 2 | 1·7 |
| ?*Atrypina* | 1 | 0·4 | — | — |
| atrypaceids indet. | 2 | 0·9 | 1 | 0·9 |
| *Meristina obtusa* (J. Sowerby) | 9 | 4·0 | 3 | 2·6 |
| ?*Meristina* | — | — | 1 | 0·9 |
| athyridaceids indet. | 3 | 1·3 | 1 | 0·9 |
| *Eospirifer* | 1 | 0·4 | — | — |
| *Cyrtina* | 1 | 0·4 | — | — |
| *Howellella* | 6 | 2·7 | — | — |
| *Lophospira* | 1 | 0·4 | — | — |
| *Liospira* | 1 | 0·4 | — | — |
| ?*Liospira* | 1 | 0·4 | — | — |
| gastropods indet. | 4 | 1·8 | 1 | 0·9 |
| cephalopods indet. | 1 | 0·4 | 1 | 0·9 |
| *Palaeoneilo* | — | — | 1 | 0·9 |
| palaeotaxodontids indet. | — | — | 4 | 3·5 |
| ?*Orthonota* | — | — | 3 | 2·6 |
| bivalves indet. | — | — | 5 | 4·3 |
| *Tentaculites* | — | — | 2 | 1·7 |
| *Encrinurus* | 11* | 4·9 | 5† | 4·3 |
| *Eophacops* | 1 | 0·4 | — | — |
| phacopinids indet. | 3 | 1·3 | 6 | 5·2 |
| trilobites indet.* | — | — | 3 | 2·6 |
| *Kloedenia* | — | — | 2 | 1·7 |
| *Beyrichia* | — | — | 2 | 1·7 |
| beyrichicopinids indet. | — | — | 1 | 0·9 |
| crinoid calyces | 3 | 1·3 | — | — |

* cranidia only.
† 5 cranidia + 3 pygidia = 5 individuals.

Though not identical, the faunas have sufficient components in common to justify correlation. Particularly significant features are the abundance of enteletaceids (13% in the Ballycar fauna, 35% in the Ryninch assemblage), the prominence of rhynchonellids, and the occurrence of *Eoplectodonta duvalii* and *Meristina obtuse*. Encrinurids and phacopinids are also noteworthy components. Petrographic characters suggest that both deposits are turbidites.

The Ballycar fauna is associated with siltstone-banded argillites having numerous coarser sandstone horizons averaging around 0·3 m in thickness. Though exposure is unfavourable to the preservation of sole-marks, the sandstones have the composition of lithic greywackes, and are also interpreted as turbidites. It was originally suggested (Weir 1962, p. 249) that the fossil horizon is the lowest level exposed in the Cratloe Hills inlier. The associated succession is identical in facies to the Broadford Group, diagnosed as the lowest stratigraphical unit present in the Slieve Bernagh

Syncline (op. cit., p. 246), and was correlated with the latter on that account. Due to scarcity of associated exposure the stratigraphical context of the Ryninch fauna is less clear, though it lies along the strike of the main outcrop of the Broadford Group in the Slieve Bernagh inlier, and close to that of its inferred contact with the succeeding Craglea Group. Reference of the Ryninch fauna to the Broadford Group would support correlation of the Ballycar succession with the latter.

Following re-examination of the Ballycar fauna, the author's original diagnosis of a Llandovery age (op. cit., p. 249) can no longer be sustained. *Salopina*, *Eoplectodonta duvalii*, and *Eophacops* have been recognized, and *Eocoelia biloba* s.s., *Leangella segmentum*, and *Meristina obtusa* specified. Together these denote a late Wenlock age, and rule out the Llandovery diagnosis. Moreover, no form specific to the Llandovery occurs (L. R. M. Cocks, pers. comm.).

This new interpretation accords well with recent amplification of the knowledge of the regional stratigraphy. Recent discoveries of dark and mottled graptolitic shales in the Slieve Bernagh inlier yield a *crispus* fauna (A. M. Flegg, pers. comm.), and continuity of the graptolitic facies from the Belvoir and Ballyvorgal Groups of the Broadford Mountains (Glenkiln–Upper Hartfell; Weir 1962, 1973) through the Llandovery of the Raheen Bridge inlier (Rickards and Archer 1969; Weir 1973) to this level may be inferred. The geographically isolated and unfossiliferous redbed facies of the Cloontra Group, which crops out within the faulted core of the Broadford Mountains Anticline and on its southern limb, probably succeeds the graptolitic facies. The group may represent a diachronous southward extension of the redbed development within the Lough Mask Formation of Connemara (Piper 1972, p. 37). The latter group is assigned to the *crispus* Zone (Cocks, Holland, Rickards and Strachan 1971, text-fig. 8), i.e. roughly contemporary with the top of the Slieve Bernagh graptolitic facies and inferentially earlier than the Cloontra Group. The latter group is probably of uppermost Telychian (?*griestoniensis*) age, leaving the Broadford Group—interpreted as succeeding the Cloontra Group conformably—to span the greater part of the Wenlock. On this basis there is an impressive acceleration in rate of deposition during the uppermost Wenlock. The Broadford Group has a thickness of some 2000 m, whereas the succeeding Craglea and Moylussa Groups, which, together with the Ballycar–Ryninch fossil horizon are assigned to the late Wenlock (cf. Harper and Brenchley 1972, pp. 259–260), have a thickness aggregating around 6000 m (Weir 1962, p. 235).

On the knowledge then available, the author suggested (1973) that the southwestward continuation of the axial rise of the Moffat geosyncline may pass close to the Tomgraney inlier. The horizon of the turbidite incursion being obliterated there by faulting, the axial rise could equally be located within Slieve Bernagh. In any event the turbidite influx took place substantially later in Clare than in the Southern Uplands, wherein it took place around *maximus* times (cf. Toghill 1970).

Significant contrasts exist between the two faunas under discussion. A proportion of these must relate to the strong selective concentration of convex valves at Ryninch, accounting for instance for the high return of *Resserella* and other enteletacean pedicle valves. This factor does not, however, account for the scarcity of plectambonitaceids, the lack of pentameraceids, and above all of corals, nor for the appearance of bivalves which are not recorded from Ballycar. These contrasts are

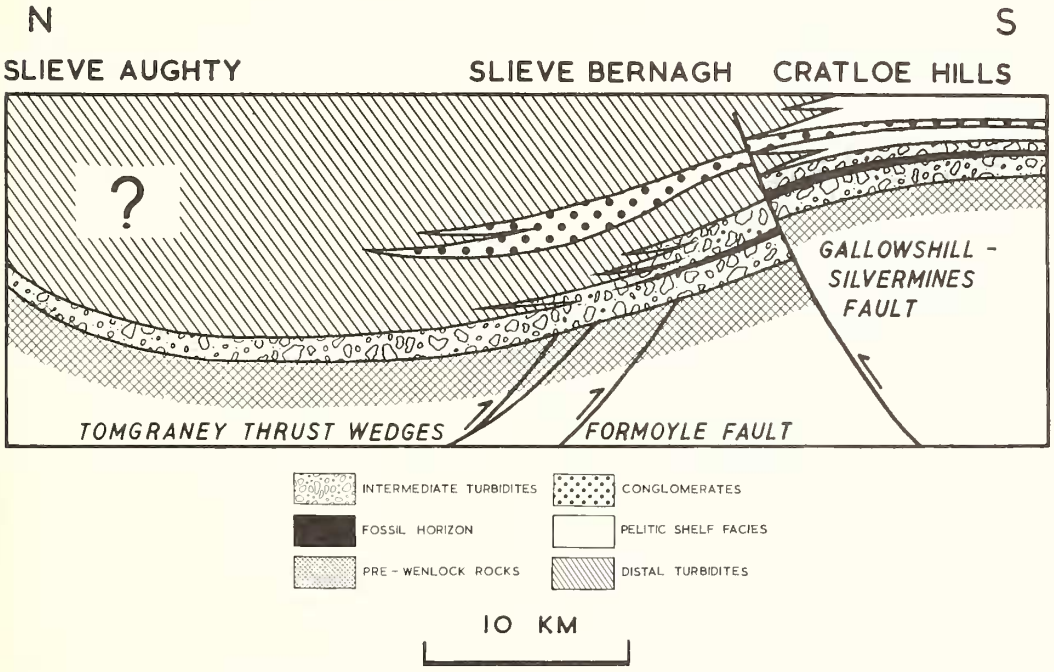
more reasonably to be ascribed to community differences in the source areas. The most obvious cause of contrast would be the drawing of the two faunas from different depth-zones. Since, however, the deposits are allochthonous, nothing can be directly deduced concerning bottom conditions in the original habitats, and in particular of the substrates colonized. Caution must therefore be exercised against over-rigorous reference to the depth-controlled Wenlock communities of Hancock, Hurst and Fürsich (1974). The Ballycar assemblage is, however, dominated by small enteletaceids and *Leangella*, appropriate to the *Dicoelosia* community (op. cit., p. 152). This is a deep-water facies corresponding to the *Clorinda* community of the Llandovery (Ziegler 1965; Ziegler, Cocks and Bambach 1968). Larger shells, including the stropheodontids, suggest incorporation of elements of the shallower *Isorthis*, *Homeospira*, and *Salopina* communities, which equate respectively with the *Pentamerus*, *Costistricklandia*, and *Lingula* communities of the Llandovery. This admixture may denote the sampling of more than one source. The preponderance of small enteletaceids at Ryninch suggests a source mainly within the deeper communities, though even here the occasional large stropheodontid hints at a composite origin. The contrasts may equally be related to local environmental factors including nature of substrate, bottom-current intensity, salinity, and oxygenation, none of which can be assessed directly.

Palaeogeographically the *Dicoelosia* community represents the second-outermost shelly community of the Upper Silurian, being separated from the graptolitic facies by the *Visbyella* community. This has no Llandovery counterpart, as the *Clorinda* community gives way to graptolitic assemblages. Depths of up to 1500 m are deduced (Hancock, Hurst and Fürsich 1974, p. 152). *Cardiola* and graptolites, which characterize the autochthonous assemblage of the Cratloe Hills and Devilsbit inliers, are also prominent members of this community, and indicate that this assemblage may have been laid down at around this depth.

The Broadford Group has no precise counterpart in the Southern Uplands turbidite successions. Walton's 'Kirkcolm' facies (1963, p. 84) shows points of resemblance in consisting of medium-grained turbidites of moderate thickness interspersed with argillites, many of them laminated. The turbidite beds are, however, characteristically much thicker than the intervening argillites, which is in direct contrast to the 'Broadford' facies. Walton diagnoses the 'Kirkcolm' facies as the deposit of an offshore environment. The much lower return of arenites, etc., in the 'Broadford' facies suggests deposition even further offshore. No autochthonous fauna has yet been recorded from the 'Broadford' facies, though the occurrence of graptolites in facies of 'Kirkcolm' type (cf. for instance Craig and Walton 1959; Rust 1965, p. 104), suggests that these might also be expected to occur in the 'Broadford' facies.

Other than one diagnosis of northerly or north-westerly current flow, from a Wenlock conglomerate of the succeeding Craglea Group of the Slieve Bernagh inlier (Weir 1960), no reliable palaeocurrent data are as yet available for the Slieve Bernagh area, though the westward and northward thinning of this conglomerate does support north-westward transport, and is of importance in Harper and Brenchley's diagnosis of a north-westward palaeoslope during the Wenlock (1972, p. 262). The Ryninch horizon contrasts with the Ballycar fossil bed in its finer grain

size, its lesser thickness, and the highly abraded state of its fossils, all of which point to a greater distance of transport and again support a general northerly descent of the palaeoslope. The Gallowshill–Silvermines Fault defined a break-of-slope, inferentially a submarine fault-scarp, the upthrow side of which housed a *Visbyella* community and thus lay at a depth of around 1500 m. The south-eastward rise of the palaeoslope would be sustained beyond the fault-scarp through successive depth-communities, at an angle sufficient to sustain the flow of the turbidity current which sampled them. Eventual emergence is suggested by the coarseness of certain of the fluxoturbidite-conglomerates. The location of any such landmass is not yet clear, but was probably some kilometres to the south-east.




TEXT-FIG. 2. Diagrammatic section across the Slieve Aughty basin and the Munster shelf, at the close of Silurian deposition. Vertical dimension exaggerated. The succession in Slieve Aughty is as yet largely hypothetical and is queried.

Triggering of the turbidity current was probably related to movement along the Gallowshill/Silvermines–Nenagh/Navan fault-complex. Tectonic conditions earlier in the Wenlock had been markedly unstable, as testified by the numerous turbidite beds (of which the Ballycar–Ryninch horizon is probably the thickest and coarsest). Deposition of the latter ushered in a period during which active differential subsidence of the Slieve Bernagh–Slieve Aughty basin took place. A contrast in sedimentary facies also developed, thin and predominantly pelitic sedimentation taking place on the margin of the Limerick–Tipperary Shelf, and banded argillites with thick fluxoturbidite-conglomerate horizons being laid down in the basin.

*Acknowledgements.* The author wishes to record his indebtedness to Professor Alwyn Williams, Dr. A. M. Flegg, Professor E. K. Walton, Mrs. Margaret Bradshaw, and Dr. A. M. Hopgood for their advice and guidance. Dr. L. R. M. Cocks vetted the identification and dating of the two faunas and commented on the text. Loan of specimens from the Geological Survey of Ireland Collection is also acknowledged.

Field work at Ballycar was initiated under a D.S.I.R. research studentship at The Queen's University of Belfast. The study of the Arra Mountains locality, carried out in association with the St. Andrews University Southern Uplands Research Group, was financed by the University Court. Appreciation of these awards is gratefully expressed.

## REFERENCES

BOUCOT, A. J., BRACE, W. and DE MAR, R. 1958. Distribution of brachiopod and pelecypod shells by currents. *J. sediment. Petrol.* **28,** 321–332.

COCKS, L. R. M., HOLLAND, C. H., RICKARDS, R. B. and STRACHAN, I. 1971. A correlation of Silurian rocks in the British Isles. *Jl geol. Soc. Lond.* **127,** 103–136.

COPE, R. N. 1954. The Silurian rocks of the Devilsbit Mountains. *Univ. Liverpool Ph.D. thesis* (unpubl.).

—— 1959. The Silurian rocks of the Devilsbit Mountain district, County Tipperary. *Proc. R. I. Acad.* B, **60,** 217–242.

CRAIG, G. Y. and WALTON, E. K. 1959. Sequence and structure in the Silurian rocks of Kirkcudbrightshire. *Geol. Mag.* **96,** 209–220.

FOOT, F. J. 1861. Explanations to accompany Sheet 134 of the map of the Geological Survey of Ireland. *Mem. geol. Surv. Ireland.*

—— and KINAHAN, G. H. 1862. Explanations to accompany Sheet 133 of the map of the Geological Survey of Ireland. Ibid.

HANCOCK, N. J., HURST, J. M. and FÜRSICH, F. T. 1974. The depths inhabited by Silurian brachiopod communities. *Jl geol. Soc. Lond.* **130,** 151–156.

HARPER, J. C. and BRENCHLEY, P. J. 1972. Some points of interest concerning the Silurian inliers of southwest central Ireland in their geosynclinal context: a statement. Ibid. **128,** 257–262.

MARTIN-KAYE, P. 1951. Sorting of lamellibranch valves on beaches in Trinidad, B.W.I. *Geol. Mag.* **88,** 432–434.

PIPER, D. J. W. 1972. Sedimentary environments and palaeogeography of the late Llandovery and earliest Wenlock of North Connemara, Ireland. *Jl geol. Soc. Lond.* **128,** 33–52.

RICKARDS, R. B. and ARCHER, J. B. 1969. The Lower Palaeozoic rocks near Tomgraney, Co. Clare. *Sci. Proc. R. Dubl. Soc.* Ser. A, **3,** 219–231.

RUST, B. R. 1965. The stratigraphy and structure of the Whithorn area of Wigtownshire, Scotland. *Scott. J. Geol.* **1,** 101–133.

TOGHILL, P. 1970. The south-east limit of the Moffat Shales in the upper Ettrick Valley region, Selkirkshire. Ibid. **6,** 233–242.

WALTON, E. K. 1963. Sedimentation and structure in the Southern Uplands. *In* JOHNSON, M. R. W. and STEWART, F. H. (eds.). *The British Caledonides,* 71–97. Edinburgh.

WEIR, J. A. 1960. Mudstone inclusions in Salopian conglomerates from Co. Clare. *Geol. Mag.* **97,** 283–288.

—— 1962. Geology of the Lower Palaeozoic inliers of Slieve Bernagh and the Cratloe Hills, County Clare. *Sci. Proc. R. Dubl. Soc.* Ser. A, **1,** 233–263.

—— 1973. Lower Palaeozoic graptolitic facies in Ireland and Scotland: review, correlation, and palaeogeography. Ibid. **4,** 439–460.

ZIEGLER, A. M. 1965. Silurian marine communities and their environmental significance. *Nature, Lond.* **207,** 270–272.

—— COCKS, L. R. M. and BAMBACH, R. K. 1968. The composition and structure of Lower Silurian marine communities. *Lethaia,* **1,** 1–27.

J. A. WEIR

Department of Geology
University of St. Andrews
Fife, Scotland

Typescript received 22 April 1974
Revised typescript received 10 August 1974